5. COMPOSTING

This chapter presents estimates of greenhouse gas (GHG) emissions and carbon sequestration from composting of yard trimmings and food scraps.[49]

Composting consists of the aerobic decomposition of organic materials. In controlled composting operations, organic materials are typically placed in piles that have sufficient moisture and aeration for aerobic microorganisms (e.g., bacteria) to decompose the materials. Aeration may be provided by turning the piles; this prevents the development of low-oxygen conditions in the piles which could lead to anaerobic decomposition, with its associated noxious odors and methane generation. Nitrogen may be added to a compost pile to achieve a carbon/nitrogen ratio that is optimal for rapid composting.

As organic materials are composted, they are converted into a form of organic matter known as humus. When the compost is added to soil, the humus decomposes further. At both stages of decomposition, much of the carbon in the original material is released in the form of carbon dioxide. Because this carbon dioxide is biogenic in origin, it is not counted as a greenhouse gas (as explained in Section 1.6). However, it is conceivable that composting could result in (1) methane emissions from anaerobic decomposition, or (2) long-term carbon sequestration in the form of undecomposed carbon compounds. In addition, with centralized composting there are non-biogenic CO_2 emissions from collection and transportation of the organic materials to the central composting site, and from mechanical turning of the compost pile.[50] Therefore, we investigated the extent to which composting might result in (1) methane emissions, (2) carbon sequestration in soils to which compost is applied (for yard trimmings, we considered the incremental carbon sequestration from composting, beyond the carbon sequestration expected when yard trimmings are left in place on the ground) and (3) CO_2 emissions from transportation of compostable materials, and turning of the compost piles.

Our analysis suggests that composting, when properly done, does not result in methane generation, and results in minimal carbon sequestration for yard trimmings. For centralized composting, slight GHG emissions result from transportation of material to be composted and mechanical turning of the compost. Overall, centralized composting of yard trimmings probably has no net GHG emissions (measured as GHG emissions minus carbon sequestration). Similarly, backyard composting of food scraps is estimated to have no net GHG emissions.

5.1 POTENTIAL GREENHOUSE GAS EMISSIONS

Two potential types of GHG emissions are associated with composting · (1) methane from anaerobic decomposition, and (2) non-biogenic CO_2 from transportation of compostable materials, and turning of the compost piles.

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[49] Although paper and mixed MSW can be composted, we did not analyze the GHG implications of composting them because of time and resource constraints.

[50] CO_2 emissions from delivery of compost to its final destination were not counted, because (1) compost is a marketable product and (2) CO_2 emissions from transportation of other marketable, finished goods to consumers have not been counted in other parts of this analysis.

Methane. To research the methane issue, we first conducted a literature search for articles on methane generation from composting. We identified no relevant articles published between 1991 and early 1995, and thus decided not to continue searching for earlier articles. Because the literature search was unproductive, we contacted several researchers from universities and the US Department of Agriculture to discuss the potential for methane generation, based on the nature of carbon flows during composting. Our methane analysis was based on their expert opinions.

The researchers we contacted stated that well-managed compost operations usually do not generate methane because they typically maintain an aerobic environment with proper moisture content to encourage aerobic decomposition of the materials. They also said that even if methane is generated in anaerobic pockets in the center of the compost pile, the methane is most likely oxidized when it reaches the oxygen-rich surface of the pile. Several of the researchers commented that anaerobic pockets are most likely to develop when too much water is added to the compost pile; however, they noted that this problem rarely occurs because compost piles are much more likely to be watered too little, rather than too much.

For backyard composting, the compost pile is rarely large enough to permit anaerobic conditions to develop, even in the center of the pile (i.e., all parts of the pile are close enough to the surface to remain oxygenated).

We concluded from the available information that methane generation from backyard and centralized compost piles is negligible.

Carbon Dioxide from Transportation of Materials and Turning of Compost. Next, we estimated the indirect carbon dioxide emissions associated with collecting and transporting yard trimmings to centralized compost facilities, and turning the compost piles. We began with estimates developed by Franklin Associates, Ltd. for the amount of diesel fuel required, for one ton of yard trimmings,[51] to (1) collect and transport the yard trimmings to a central composting facility (363,000 BTUs), and (2) turn the compost piles (221,000 BTUs).[52] We converted these estimates to units of metric tons of carbon equivalent (MTCE) per ton of yard trimmings, based on a carbon coefficient of 0.0208 MTCE per million BTUs of diesel fuel. This resulted in an estimate of 0.01 MTCE of indirect CO_2 emissions per ton of material composted in a centralized facility. There are no indirect CO_2 emissions from backyard composting, because there is no significant use of machinery to transport materials or to turn the compost pile.

5.2 POTENTIAL CARBON SEQUESTRATION

We also evaluated the effect on carbon storage of composting yard trimmings and food scraps.

Yard Trimmings. For yard trimmings, our analysis compared the amount of long-term carbon storage when yard trimmings are composted (and subsequently applied to soil) to the amount of carbon storage when the trimmings are left directly on the ground to decompose. Because we were unable to find data allowing us to quantify incremental carbon storage, we used a bounding analysis to estimate the upper and lower limits of the magnitude of this phenomenon.

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[51] Measured on a wet weight basis, as MSW is typically measured.

[52] Franklin Associates, Ltd., *The Role of Recycling in Integrated Solid Waste Management to the Year 2000* (Stamford, CT: Keep America Beautiful), pp. I-27, I-30, and I-31.

During the process of decomposition, organic materials typically go through a series of steps before finally being converted to CO_2 (as well as water and other reaction products). The intermediate compounds that are formed, and the lifetime of these compounds, can vary widely depending on the chemical composition of the parent compound; the availability of oxygen and nutrients; the population of microorganisms capable of degrading the compounds; temperature and moisture conditions; and many other factors. To evaluate the potential of composting to enhance carbon storage, a useful simplification is to view decomposition as a process consisting of two phases:

- a rapid degradation phase, lasting for a few months to a few years, where the readily degradable materials are converted mostly to CO_2, and to a much lesser extent to humic materials, and

- a slow degradation phase, lasting much longer, where the humic materials are slowly degraded to CO_2.

Composting is designed to accelerate the pace of the first phase. It promotes rapid decomposition of organics, thus reducing their volume. Some evidence suggests that composting produces a greater proportion of humus than that typically formed when yard trimmings are left directly on the ground. The conditions in the two settings are different · the heat generated within compost piles favors "thermophilic" (heat-loving) bacteria, which tend to produce a greater proportion of stable, long-chain carbon compounds than do bacteria that predominate at ambient surface temperatures. These long-chain carbon compounds include lignin and humic materials (humic acids, fulvic acids, and humin).

For our analysis, we assumed that in soils where trimmings (i.e., grass clippings, leaves, and branches) are left in place, there is no net accumulation of carbon in the soil. This assumption is consistent with the observation that the quantity of carbon emitted from soils as carbon dioxide each year is typically in equilibrium with the quantity of additional carbon introduced into the soil each year by roots, leaf litter, and branches.[53] We used this scenario as our baseline against which to measure incremental carbon storage attributable to composting.

The incremental storage is a function of three principal factors:

(1) The amount of carbon in each material (grass, leaves, branches),

(2) The additional proportion of carbon converted into humus when trimmings are composted, rather than left in place, and

(3) The rate at which humus is degraded to CO_2.

We obtained point estimates for the first factor from a series of experiments by Dr. Morton Barlaz, which are described later in Chapter 7. As in other parts of the analysis, we assumed that yard trimmings

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[53] Alexander, Martin, *Introduction to Soil Microbiology, Second Edition* (Malabar, Florida: Krieger Publishing Company) 1991, p. 133.

comprise 50 percent grass clippings, 25 percent leaves, and 25 percent branches, by weight.[54] We used professional judgment to develop lower and upper bound estimates for the second and third factors, and then combined the estimates in a bounding analysis.

As an upper bound on the incremental humus formation, we assumed that composting can result in conversion of up to 25 percent more of the carbon to humus than the "baseline" conversion rate (i.e., if residues were left on the ground).[55] (This upper bound implies, for example, that if 10 percent of the carbon is in a relatively stable form following decomposition at ambient temperatures, then 35 percent of the carbon would be relatively stable after composting.) For a lower bound, we used a value of 5 percent as the incremental portion of carbon that is converted to stable carbon compounds.

We also developed a range for the half-life of stable carbon compounds in soil. Radiocarbon dating of soils has shown that the long-chain carbon compounds in some soil samples can be hundreds or thousands of years old.[56] As noted above, the decay rate of individual compounds is highly site- and compound-specific; to account for this heterogeneity, we used wide bounds · from a half-life of 20 years to a half-life of 2,000 years. We assumed that humus decomposition is a first-order decay process (i.e., the proportional decrease in concentration is constant over time).

Combining the two bounds for incremental humus formation (5 percent and 25 percent) and the two bounds for half-lives (20 years and 2,000 years) resulted in four scenarios for the bounding analysis. We estimated the incremental carbon storage implied by each scenario over a period of 100 years.

The results of our bounding analysis are shown graphically in Exhibit 5-1. The upper bound on the incremental carbon storage from composting is about 0.05 MTCE per ton of yard trimmings (shown in the top left of the graph); the lower bound is about 0.001 (shown in the bottom right of the graph). With the rapid decomposition (20 year half-life) assumption, incremental storage is quite sensitive to the time period over which carbon storage is considered · values at 20 years are sixteen times as high as values at 100 years. Under the slow decomposition assumption, there is little difference in incremental storage for all periods up to 100 years.

<u>Food Scraps</u>. We also estimated the carbon storage from backyard composting of food scraps. Data were not available on the amount of carbon sequestered in humus when food scraps are composted. We assumed that backyard composting of food scraps converts all of the carbon in food scraps to CO_2, and that none of the carbon is sequestered in humus. To the extent that backyard composting of food scraps may sequester carbon, our results would understate the net carbon sequestration resulting from composting this material.

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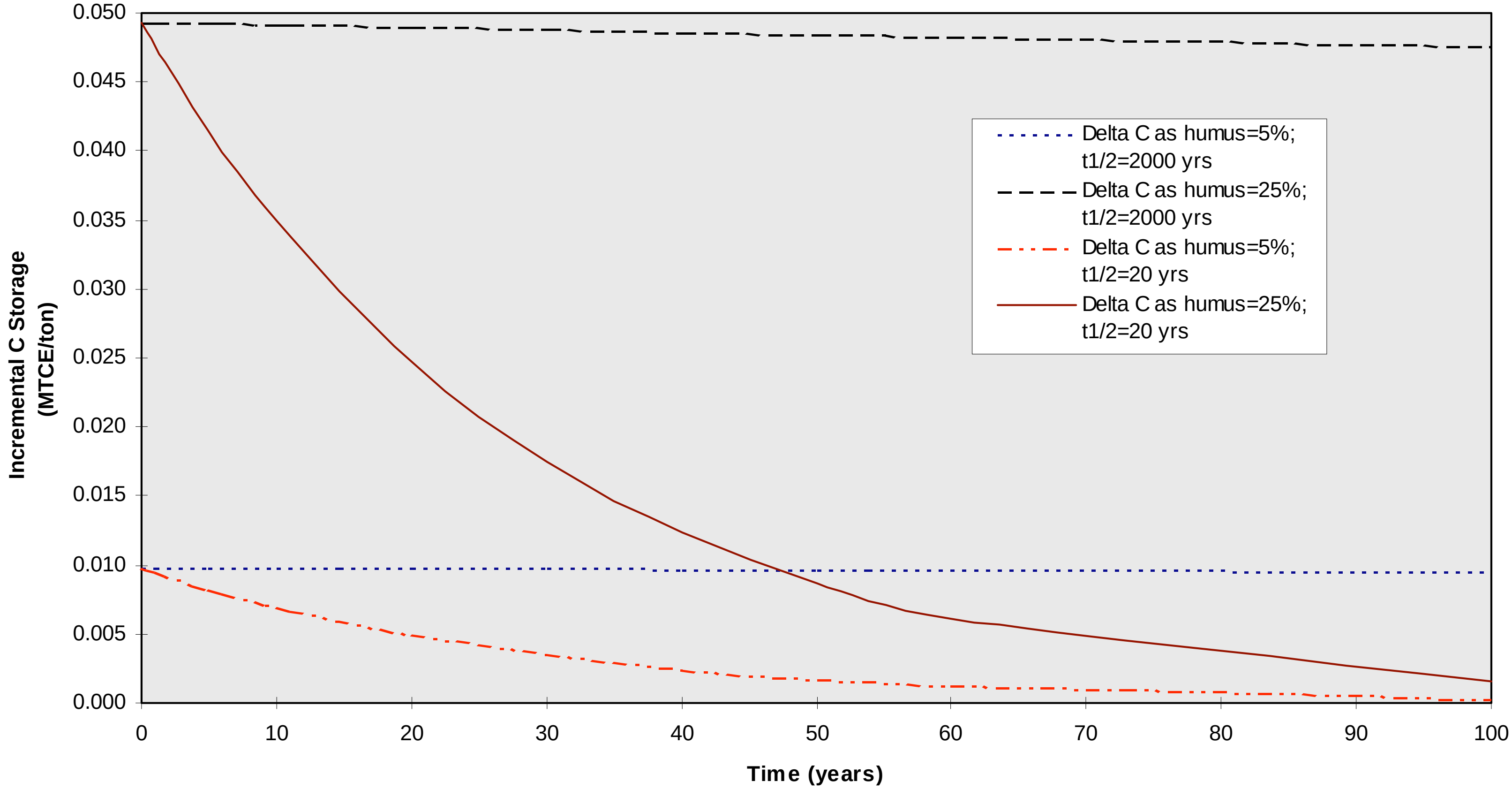
[54] This professional judgment estimate for the percentage composition of yard trimmings (as a national average) was provided by Nick Artz of Franklin Associates, Ltd. (FAL) in a telephone conversation with William Driscoll of ICF Incorporated, November 14, 1995. Subsequently, FAL obtained and provided data showing a wide range of percentage breakdowns for yard waste composition in different states; the percentage composition used here is within that range.

[55] Memorandum from Michael Cole, University of Illinois at Urbana-Champaign to George Garland, U.S. EPA Office of Solid Waste, February 1, 1996.

[56] Allison, F.E., *Soil Organic Matter and Its Role in Crop Production* (Elsevier Scientific Publishing Co.) 1973, pp. 157-8.

Exhibit 5-1. Incremental Carbon Storage:
Composting Yard Trimmings
MTCE/wet ton vs time



5.3 NET GHG EMISSIONS FROM COMPOSTING

Exhibit 5-2 presents the estimated net greenhouse gas emissions from composting. Our analysis indicated that composting is a process that produces virtually no greenhouse gas emissions, and is not likely to represent a significant carbon sink. For centralized yard trimmings composting, the transportation emissions are probably balanced (and could well be exceeded) by additional carbon storage. Given the large tonnage of yard trimmings composted annually, and the remaining uncertainties in this analysis, this is an area that would benefit from further study. For backyard food waste composting, we estimated no net GHG emissions.

EXHIBIT 5-2
Net Greenhouse Gas Emissions from Composting
(In Metric Tons of Carbon Equivalent Per Short Ton of Material Composted)

Material	Centralized Composting				Backyard Composting			
	CH_4	Transport CO_2	C seq	Net C	CH_4	Transport CO_2	C seq	Net C
Yard Trimmings	0	0.01	0.001 to 0.05	0.009 to -0.49	NA	NA	NA	NA
Food Scraps	NA	NA	NA	NA	0	0	0	0

5.4 LIMITATIONS OF THE ANALYSIS

The analyses in this chapter are limited by the lack of data on methane generation and carbon sequestration that result from composting. Because of inadequate data, we relied on a theoretical approach to estimate the values (and in the case of carbon sequestration from composting of food scraps, we assumed zero carbon sequestration).

Our analysis did not consider the GHG emissions that might be avoided if compost displaces some chemical fertilizers (or peat moss, fungicides, pesticides, and other products applied to soil and plants). The manufacture of chemical fertilizers requires energy, and thus is associated with some level of energy-related GHG emissions. We also did not analyze the extent to which compost may reduce the need for pesticides.[57,58] For the most part, compost is applied for its soil amendment properties, rather than for purposes of fertilization or pest control.

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[57] For example, the use of compost may eliminate the need for soil fumigation with methyl bromide (an ozone-depleting substance) to kill plant pests and pathogens.

[58] EPA plans to investigate in 1997 the GHG impacts of substituting compost for fertilizer.

Moreover, we did not consider other environmental benefits of composting, and of using compost as a soil amendment. For example, adding compost to soil increases the soil's capability to retain moisture and nutrients. This helps to reduce storm runoff, thus preserving topsoil and reducing siltation of streams and rivers. In the future, this may allow continued farming in areas that might have more frequent droughts due to climate change. Adding compost to soil also improves soil tilth and reduces soil density, i.e., it makes the soil easier to till, allows plant roots to go deeper, increases the likelihood that new plantings become established, and helps plants to grow larger. Finally, we did not consider the value of composting in reducing the amount of waste landfilled, and extending the useful lifetime of landfills.

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